April 25, 2001

An Outline of a Monitoring Program for Estimating the State of Water Temperature In the Columbia and Snake Rivers

John Yearsley
EPA Region 10
Seattle, Washington

The importance of water temperature for the Columbia River ecosystem has been the topic of scientific analysis and discussion for several decades. The work of Raphael (1962), for example, represents one of the first efforts to apply the energy budget method to a major river system. A workshop convened in 1963 by the Federal Water Pollution Control Commission represented an early effort on the part of regional scientists to discuss biological, physical and chemical effects of water temperature. Davidson (1964) analyzed long term records of the Columbia River for purposes of characterizing the effects of Wells, Rocky Reach, Wanapum and Priest Rapids dams on the temperature of the Columbia River. Davidson (1964) also observed that storage of deep water in Arrow Lake in Canada was a potential source of cold water for a period of 30 to 50 days in the summer. Studies by Battelle (Jaske and Synoground, 1970), under contract to the Atomic Energy Commission (AEC), described the impacts of Grand Coulee Dam and Lake Roosevelt on the temperature regime of the Columbia and also demonstrated the potential for using releases of cold water from Grand Coulee for downstream temperature control.

The Columbia River Thermal Effects Study was initiated by the Department of Interior in January 1968 to develop consistent water quality standards for the states of Oregon and Washington. The study was motivated by the sense that upriver runs of Columbia River fish had been reduced and endangered by the physical alteration and blockage of migration routes by the nation's largest system of dams and reservoirs, and that Columbia River temperatures had been both spatially and temporally altered by man's activities. The research conducted during the study contributed to much of our existing knowledge of temperature effects on Pacific salmon. In addition, the study produced a working mathematical model of water temperature of the Columbia River from the International Border to its mouth near Astoria, Oregon.

The agencies that operate the dams on the Columbia and Snake rivers showed little interest in the results of these studies until recently, when several *Evolutionary Significant Units* were listed as threatened or endangered under the Endangered Species Act, and segments of both rivers were listed as water-quality limited for temperature under Section 303 of the Clean Water Act. This lack of interest is reflected in the state of the temperature monitoring programs on the Columbia and Snake rivers. Prior to 1984, measurements of water temperature in Columbia and Snake consisted of manual observations of temperature from thermometers placed in the cooling water stream of each dam's turbines. These observations, generally described as scroll case measurements were made on a daily basis by dam operations personnel. A recent evaluation of these measurements (Cope, 2001) found many deficiencies in the instruments, in the location of the instruments and the protocols for collecting and reporting data. Many of these deficiencies appeared to be related to the original motivation for installing the thermometers, which was for purposes of monitoring the operation of turbines rather than for analyzing temperature effects on Pacific salmon.

Temperature monitoring associated with the total dissolved gas program was initiated in 1984 at many of the dams. In contrast to the scroll case temperature monitoring program, the focus of the total dissolved gas monitoring was on characterizing the state of water temperature in the rivers rather than on monitoring the operation of machinery in the project. Nevertheless, the resulting data, as compiled by McKenzie and Laenen (1998) and reported on the Columba River Web site for Data Access in Real Time (DART) site shows a lack of attention to quality control. One also has the feeling that the temperature measurements are primarily an adjunct to the total dissolved gas monitoring rather than an effort to adequately estimate the state of water temperature in the Columbia and Snake rivers. A sample of 29 year-long records on the Columbia River (Columbia River at International Boundary, Columbia River at Grand Coulee) and the Snake River(Ice Harbor Dam forebay and tailrace, Little Goose Dam forebay and tailrace) found that 14 of the records had either large gaps of missing data or large portions of data that were clearly erroneous. Figure 1 is an example of data that are clearly erroneous.

It has become clear that sound scientific methods for estimating the state of water temperature in the Columbia and Snake rivers are needed to address issues of endangered species and failure to meet water quality standards of the states of Idaho, Oregon and Washington. Two essential elements of any monitoring program, elements that are not present in the existing program on the Columbia and Snake rivers, are a clearly defined set of objectives and a well-designed quality assurance/quality control plan. The objective of the monitoring program described below is to obtain adequate state estimates of water temperature in the Columbia and Snake rivers for purposes of developing a Total Maximum Daily Load (TMDL) as required by Section 303 of the Clean Water Act. EPA can also provide technical assistance for development of an adequate quality assurance/quality control plan. The plan of action for dissolved gas monitoring (February 2001) contains many of the concepts that would be needed for an adequate river temperature monitoring program (as noted above, the dissolved gas plan treated water temperature measurements as an adjunct to the total dissolved gas program).

A monitoring program that meets the objectives of developing a temperature TMDL for the Columbia and Snake rivers should include the components described below. This level of monitoring should be conducted for a period of at least five years. After five years, the plan should be revised and modified based on reduced uncertainty in model estimation parameters.

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Flow

Daily river flow measurements are required for the main stem Snake and Columbia and for major tributaries. Measurements of river flows, as presently conducted and reported by the USGS, provide an adequate network of data and meet standards of quality control/quality assurance.

Temperature

Water temperature measurements are required at existing total dissolved gas monitoring sites. Additional spatial coverage should be provided at all the total dissolved gas tailrace sites (or at a separate location such as a bridge crossing) that would provide the capability for characterizing the cross-sectional average of water temperature. A minimum design at these sites would be a total of nine locations configured as three equally-spaced moorings across the width of the river, with three temperature probes per mooring at approximately equally-spaced intervals in the vertical. In addition, single, continuous temperature monitoring sites should be located at the mouth of major tributaries including the Kettle River, Colville River, Spokane River, Yakima River, Salmon River, Grande Ronde River and the Clearwater River at Orofino. Weekly observations at smaller tributaries, as described in Yearsley (1999), are needed for the period April-October. Monthly observations in these tributaries are sufficient during the remainder of the year. Particular attention should be given to quality assurance/quality control at all temperature monitoring sites.

Reservoir Elevation

Reservoir elevation measurements are required at all locations presently reported on the Columbia River DART. Particular attention should be given to improving these measurements at Grand Coulee and Dworshak dams, where small errors in the measurement of surface elevation introduce significant error into the water budgets.

Reservoir Operation

Measurements of flow from the various hydroelectric operations are required at all projects. This includes the flow through all turbines, spillway and outlet facilities. These measurements are particularly important at Grand Coulee and Dworshak, where vertical stratification plays in important role in the downstream temperature regime.

River Geometry

Adequate river geometry (river cross-sections in HEC-2 format) are required at approximately one-mile intervals throughout the main stem Snake and Columbia rivers.

Meteorology

An adequate network of weather observations is an essential component of this monitoring program. Weather stations that measure and record wind speed, air temperature, and moisture content (dew point, relative humidity, or wet bulb) should be sited at each hydroelectric project. Cloud cover can be observed at regional sites including the existing first-order stations maintained by the Weather Service. In addition, the U.S. Bureau of Reclamation AGRIMET sites should be modified to include cloud cover measurements.

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References

Cope, B. 2001. Site Visits to Six Dams on the Columbia and Snake Rivers, EPA Region 10, Memorandum to the files dated 4/18/2001.

Davidson, F.A. 1964. The temperature regime of the Columbia River from Priest Rapids, Washington to the Arrow Lakes in British Columbia. *Prepared for the* Public Utility District No. 2 of Grant County, Ephrata, Washington. 31 pp. + tables and figures

Jaske, R.T. and M.O. Synoground. 1970. Effect of Hanford plant operations on the temperature of the Columbia River 1964 to present. *BNWL-1345.* Battelle Northwest, Richland, Washington.

McKenzie, S.W. and A. Laenen. 1998. Assembly and data-quality review of available continuous water temperatures for the main stems of the lower- and mid-Columbia and lower-Snake rivers and mouths of major contributing tributaries. NPPC Contract C98-002, Northwest Power Planning Council, Portland, Oregon.

Raphael, J.M. 1962. Prediction of temperature in rivers and reservoirs. *J. of the Power Div. Am. Soc. Civ. Eng.* , PO 2, pp. 157-181.

Yearsley, J.R. 1999. Columbia River Temperature Assessment – Simulation Methods. EPA Region 10, Seattle, Washington. 388 pp. + appendices.

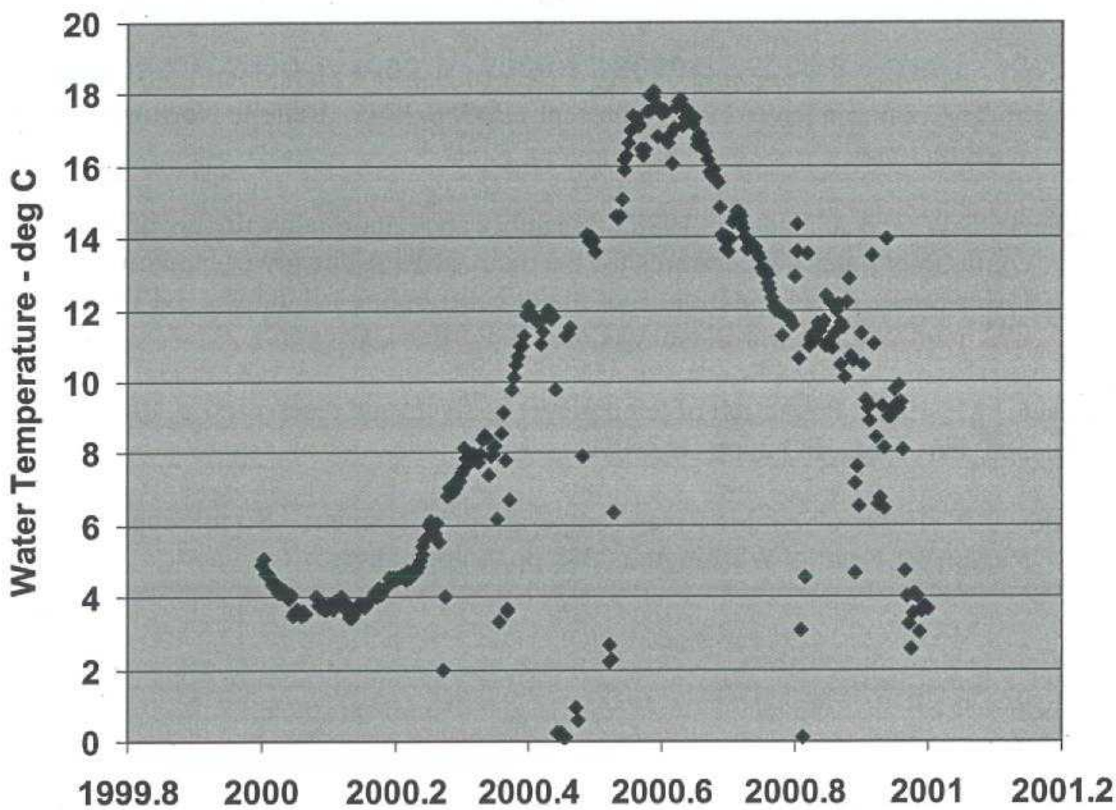

Figure 1. Water temperature at CIBW as reported on the DART Site